521282S Biosignal processing V (Lab exercises, spring 2019)

Lab – V SEP Analysis

Objective

The aim of this exercise is to analyze a multiple trial SomatoSensory Evoked Potential (SSEP) recording.

A sample of one channel EEG data is used. The data contains a synthetic 100 trial artifact free (e.g. no muscle and/or eye artifacts) SSEP recording.

In the exercise, first, the recording ensemble is visualized to demonstrate the great variability between individual trials. An ensemble average is then calculated to increase the SNR of the SSEP signal. Next, SNR of the SSEP recording is estimated. Finally, a single linear chirp model is used to model the average SSEP signal using a Particle Swarm Optimization (PSO) method.

In order to pass the exercise, all correctly executed task results marked with an arrow bullet (➢) must be personally presented to a course assistant during the scheduled laboratory exercise.

Implementation

The data and instructions needed for this exercise can be found in the Biosignal Processing II course webpage (see the Noppa system link in the footer of this document).

Download, and extract to your working folder, the SEPchirp_v101.zip containing the chirp fitting toolbox and the SSEP data vector file ‘datasample.mat’ used in this exercise. Also, download and extract the PSOt.zip that contains the PSO toolbox needed to optimize the chirp model. Familiarize yourself with Matlab ‘struct’ variable format.

Store your solutions in **a single script code m-file** that provides the required task results.

1. Raw SSEP signals and ensemble averaging

Load the data file 'datasample.mat'. The data file contains a struct variable 'data_samples' with fields 'raw_data', 'Fs', and 'amplitude_unit':

- 'raw_data' contains the SSEP EEG recordings. 100 trials of 489 samples (100ms) in each row.
- 'Fs' contains the sampling frequency.
- 'amplitude_unit' is a multiplier to convert the SSEP data to V scale.

Extract the 'raw_data' field and multiply the resulting matrix with the amplitude_unit to scale to V and then divide accordingly to get µV scale. Then, use the 'mean' function to calculate the ensemble average:

$$\hat{s}_a(n) = \frac{1}{M}\sum_{i=1}^{M} x_i(n). \tag{1}$$

- ➢ Plot the 100 raw EEG SSEP signals and the ensemble average into a same figure. Scale the time axis in milliseconds. (Tip: notice the direction of the raw data matrix, also, define the 'LineWidth' parameter when plotting the average so that it shows better amongst the raw data).

2. SNR estimation

Use the following equations (and the averaging equation (1) above):

$$\hat{\sigma}_v^2(n) = \frac{1}{M}\sum_{i=1}^{M}\left(x_i(n) - \hat{s}_a(n)\right)^2 \tag{2}$$
$$\hat{\sigma}_v^2 = \frac{1}{N}\sum_{n=0}^{N-1} \hat{\sigma}_v^2(n) \tag{3}$$
$$\hat{E}_s = \frac{1}{N}\sum_{n=0}^{N-1}\left(\hat{s}_a(n)\right)^2 \tag{4}$$
$$SNR = 10\log_{10}\left(\frac{\hat{E}_s}{\hat{\sigma}_v^2}\right) \tag{5}$$

to calculate:

- ➢ the average variance estimate $\hat{\sigma}_v^2$ for the recordings
- ➢ the mean squared signal energy estimate $\hat{E}_s$
- ➢ the *SNR* in dB
- ➢ the estimate averaging SNR dB improvement: $20\log_{10}\sqrt{M}$
- ➢ What is now the estimated SNR for the averaged signal?

(NOTE: M=100 trials *i*, N=489 samples at time instants *n* per trial.)

3. Chirp modeling

Use the 'chirp_features' function provided in the SEPchirp toolbox to fit a linear chirp model without prefilters.

The material used in this exercise can be found in the course web page at
https://noppa.oulu.fi/noppa/kurssi/521282s/harjoitukset

- To set these parameters, you need to first open the ‘chirp_features’ function and edit the toolbox code. Set the ‘model’ variable (line 64 in the code) to ‘lin’ and ‘prefiltering’ variable to zero (line 65 in the code).

The ‘chirp_features’ function takes the original data variable ‘data_samples’ as the input and gives a ‘struct’ out with multiple new fields (look at the function header for a list). NOTE: be sure that the SEPchirp and PSO Toolboxes are in the Matlab path (also subfolders)

➢ Plot the fitted chirp signal in the same figure with the previous raw data and the ensemble average (NOTE: the fitted_chirp field has already been scaled to µV)

Next, look at the model fitting results and find the values for features:

- Chirp delay
- First SEP peak amplitude
- Second SEP peak amplitude
- First SEP peak delay
- Second SEP peak delay

(NOTE: the delay values have been scaled to seconds, and the amplitudes have no sign)

➢ Plot the delays in the figure as black vertical dashed lines and the amplitudes as horizontal lines in their correct positions.

4. OPTIONAL TASKS

Find the third peak (i.e. the second positive peak) location and amplitude using the fitted chirp model. (Tip: The model has zero DC and monotonically decreasing envelope)

- Plot the third peak delay and amplitude as dashed vertical and horizontal lines in their correct positions

Notice how the third peak of the ‘lin’ fitted chirp is not very close to the ensemble average! Edit the ‘chirp_features’ function to enable ‘linexp’ model (i.e. Linear and exponential instantaneous frequency model).

- Redo all the plots with the ‘linexp’ model fitting.

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